Biogeochemistry in Los Alamos Climate, Ocean, and Sea Ice Modeling

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Geocycling of carbon by the marine biota determines to a large extent the state of planetary-scale climate and, further, its response to anthropogenic greenhouse gas release. The Climate, Ocean and Sea Ice Modeling (COSIM) project has responded to the challenge of comprehending this situation by developing and running global ocean biogeochemistry simulations. This process is accomplished by adding several dozen new tracers to the Los Alamos Parallel Ocean Program (POP). Nutrients, phytoplankton, zooplankton, bacteria, and organic detritus are all represented along with their source sink interrelationships. In essence, the COSIM team models the entire marine food web and its integrated feedbacks on climate. Geocycling processes considered include: a) large scale ecodynamics and the associated carbon drawdown, b) limitations placed upon primary production by trace forms of iron or nitrogen, and c) the role of oceanic organisms in controlling aerosol/cloud reflectivities via gas exchange.

Most biogeochemistry research conducted thus far in POP has focused on computation of phytoplankton distributions with links to carbon and iron because they are the elements most directly related to climate management [1,2]. The sulfur cycle feeds back on carbon dioxide-driven warming through sea-air transfer of the trace gas dimethyl sulfide (DMS). COSIM has developed detailed DMS processing mechanisms which have fared well in recent intercomparisons [3]. A host of other volatile species has been modeled in parallel. Examples include carbon monoxide as a critical surface ocean photochemical, carbonyl sulfide, nitrous oxide, ammonia, and a variety of pure and halogenated hydrocarbons [4].

With wholesale Arctic environmental change now at hand, COSIM biogeochemists are embarking on an effort to develop polar and general high-latitude marine systems models. For example, ice algae have now been added to the global ecodynamics structure. Interactions with sea floor sediment, the possibility of methane clathrate destabilization there, and the unique organisms of cold surface waters will all be considered. An explosion of data is now becoming available to marine systems modelers in the form of metagenomes. COSIM biogeochemists are collaborating with theoretical biologists and genomics specialists at the Laboratory in order to develop methods for informing large-scale models of the oceanic metabolism.

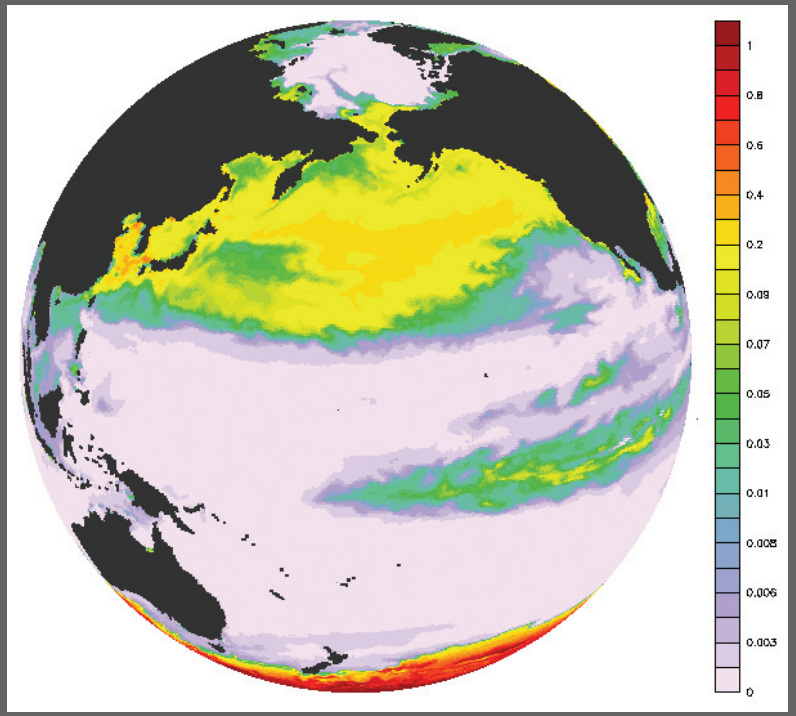

Fig. 1. Ammonia/ammonium is a major chemical form of recycled nitrogen in the marine surface mixed layer. Here distributions are shown for the North Pacific in a generic wintertime scenario simulated by POP. Transfer of ammonia into the troposphere exerts control on atmospheric pH with wide-ranging consequences. Units are micromolar.

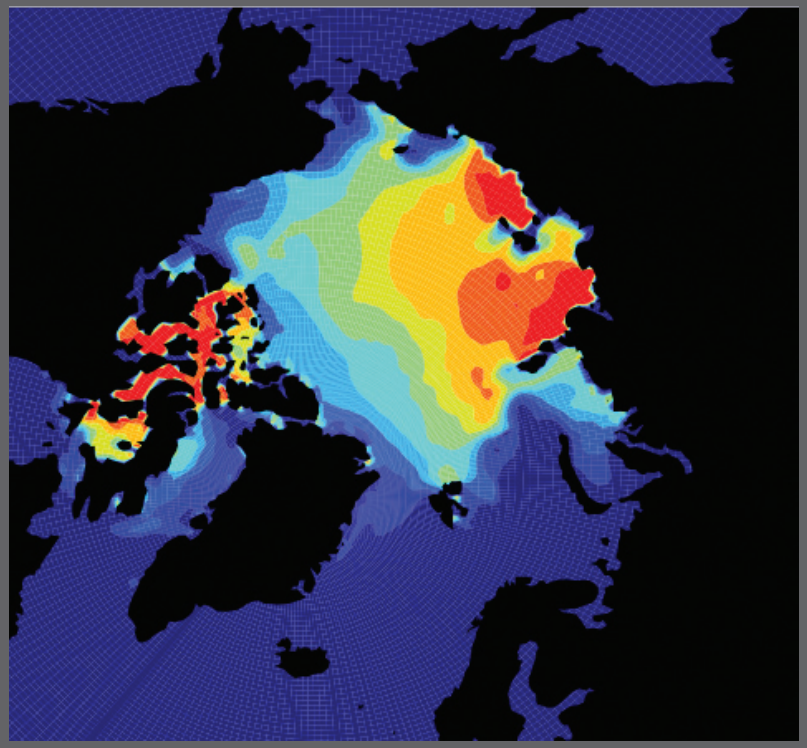

Fig. 2. Ice algal patterns simulated for late spring of 1982, in the Los Alamos Community Ice CodeE (CICE) package, which can be coupled to POP. The color bar is linear in concentration and runs from 0 (deep blue) through 10 (red) in the units millimoles of Si per square meter – the organisms are a form of pennate diatom constructing silicate frustules (shells).

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[1] S. Chu, S. Elliott, and M. Maltrud, *Chemosphere,* **50,** 223-235 (2003).
[2] L. M. Rothstein et al., *Oceanography,* **19,** 2-51 (2006).
[3] S. Elliott, S. Chu, and D. J. Erickson, *Environmental Modeling and Software,* **22,** 349-358 (2007).
[4] S. Elliott, S. Chu, and C. Dean, TRACEGAS_MOD: Geochemical Processing for Low Concentration Volatiles in the CCSM Ocean in *Environmental Sciences and Environmental Computing,* Vol. 3, FiatLux Publications, San Francisco (2008).

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